

RENEWABLE ENERGY AND OTHER ALTERNATIVE ENERGY SOURCES

Over the last 200 years, people have become more and more dependent on energy that they dig out of the ground.

In the 1700's, almost all our energy came from wind, water, firewood, or muscle power. The wind powered our windmills and sailing ships. Water powered our water wheels. Firewood did our cooking and heated our homes. Muscle power (human or animal) did just about everything else. All these energy sources came from the sun, since solar energy drove wind and rain, grew trees, and grew crops to nourish our animals and ourselves. All these energy sources were also renewable, since wind kept blowing, rivers kept flowing, and trees and crops kept growing.

About 1800, we began to get much of our energy from coal dug out of the ground. About 1900 we began to drill for oil and natural gas. By 1950 these "fossil fuels" had mainly displaced the older energy sources except for water power. Fossil fuels come from the decayed remains of prehistoric plants and animals, so their energy also comes, originally, from the sun. In some parts of the world new fossil fuels are being formed even today. But we are using fossil fuels at a far greater rate than they are being created, using up energy stored over hundreds of millions of years in a few hundred years.

After 1950, we began to use atomic energy from uranium dug from the ground. Uranium is not a fossil fuel, and its energy does not originate from the sun. But uranium, like fossil fuels, is non-renewable: once it's used up, it's gone forever.

Over the past 25 years, use of older renewable energy sources has increased and we have begun to use new renewable energy sources as well. We have realized that our fossil and atomic fuels will not last forever, and that their use contributes to environmental pollution. Renewable energy – which basically comes from the sun in one way or another – provides opportunities for an unlimited, sustainable energy supply with low environmen-

tal impact. And renewable energy is not just something for the future, but something we can use in our homes today.

What are Renewable and Alternative Energy Sources?

True renewable energy sources are energy supplies that are refilled by natural processes at least as fast as we use them. All renewable energy comes, ultimately, from the sun. We can use the sun directly (as in solar heating systems) or indirectly (as in hydroelectric power, wind power, and power from biomass fuels). Renewable energy supplies can become exhausted if we use them faster than they become replenished: most of England's forests were cut down for fuel before the English started using coal. If used wisely, however, renewable energy supplies can last forever.

There are other alternatives to our typical energy sources that are not renewable. Although these are "alternative energy" rather than "renewable energy", they use the energy we have more efficiently than older technologies. In doing this, they help us make our existing energy supplies last longer and give us more time before we run out of stored fossil and atomic fuels.

The use of renewable and alternative energy sources can save us money, assure that our grandchildren and great grandchildren will have enough energy, and free us from the uncertainties of depending on energy supplies outside the United States.

Types of Renewable and Alternative Energy

There are several renewable energy sources that are in use today. Listed below are brief descriptions of these resources; later we will discuss how some of these can be used in residential applications.

Hydropower:

Hydropower represents one of the oldest and largest renewable power sources and accounts for close to 10% of our nation's electricity. Existing hydropower capacity is about 80,000 megawatts (MW – one million watts or one thousand kilowatts). Hydropower plants convert the energy of flowing water into electricity. This is primarily done by damming rivers to create large reservoirs and then releasing water through turbines to produce electricity. Hydropower results in no emissions into the atmosphere but the process of damming a river can create significant ecological problems for water quality and for fish and wildlife habitat.

Biomass

Biomass is second to hydropower as a leader in renewable energy production. Biomass has an existing capacity of over 7,000 MW. Biomass as a fuel consists of organic matter such as industrial waste, agricultural waste, wood, and bark. Biomass can be burned directly in specially designed power plants, or used to replace up to 15% of coal as a fuel in ordinary power plants. Biomass burns cleaner than coal because it has less sulfur, which means less sulfur dioxide will be emitted into the atmosphere. Biomass can also be used indirectly, since it produces methane gas as it decays or through a modern process called gasification. Methane can produce power by burning in a boiler to create steam to drive steam turbines or through internal combustion in gas turbines and reciprocating engines.

The largest use of biomass energy in Virginia is the forest products industry. Furniture plants, sawmills, and paper mills usually burn their wood waste to produce heat and electricity. Many homeowners use firewood or pellets for winter heat.

Geothermal

Geothermal electric capacity in the United States is over 3,000 MW. Geothermal power plants use high temperatures deep underground to produce steam, which then powers turbines that produce electricity. Geothermal power plants can draw from underground reservoirs of hot water or can heat water by pumping it into hot, dry rock.

High underground high temperatures are accessed by drilling wells, sometimes more than a mile deep. In one sense, this geothermal energy is not renewable, since sometime in the future the core of the earth will cool. That time is so far off (hundreds of millions of years) that that we think of it as renewable. Most geothermal power plants are located in the western United States, but some coastal regions of Virginia (near Wallops Island) have geothermal power potential.

Geothermal heat pumps use compressors to pump heat out of the earth (for winter heating) or into the earth (when running as air conditioners in summer). The energy they pump into and out of the earth is renewable, since it is replaced by the cycle of the seasons. The energy that runs the compressor can either be renewable or conventional.

Solar Energy

Solar energy comes directly from the power of the sun and is used to produce electricity, to produce heat, and for light. Solar represents a small share of the electric market in the United States – about ½ of one percent of electrical capacity. Solar's contribution to heating and lighting is much larger.

Solar-electric power can be produced either by power plants using the sun's heat or by photovoltaic (PV) technology, which converts sunlight directly to electricity using solar cells. PV technology is more practical for residential use.

Systems to use the heat of the sun directly can be either active or passive. In active systems, air or liquid circulate through solar collectors and bring heat to where it is used. In passive systems, buildings are built with windows and heat-absorbing surfaces set up to maximize solar heating in winter. Either technology is suitable for residential use.

Systems to directly use the light of the sun are most common. The most usual device for using sunlight is the window, but skylights and skylight tubes are also used.

Wind Power

Wind energy represents 4,700 megawatts (MW) of installed electric capacity in the United States. Wind has

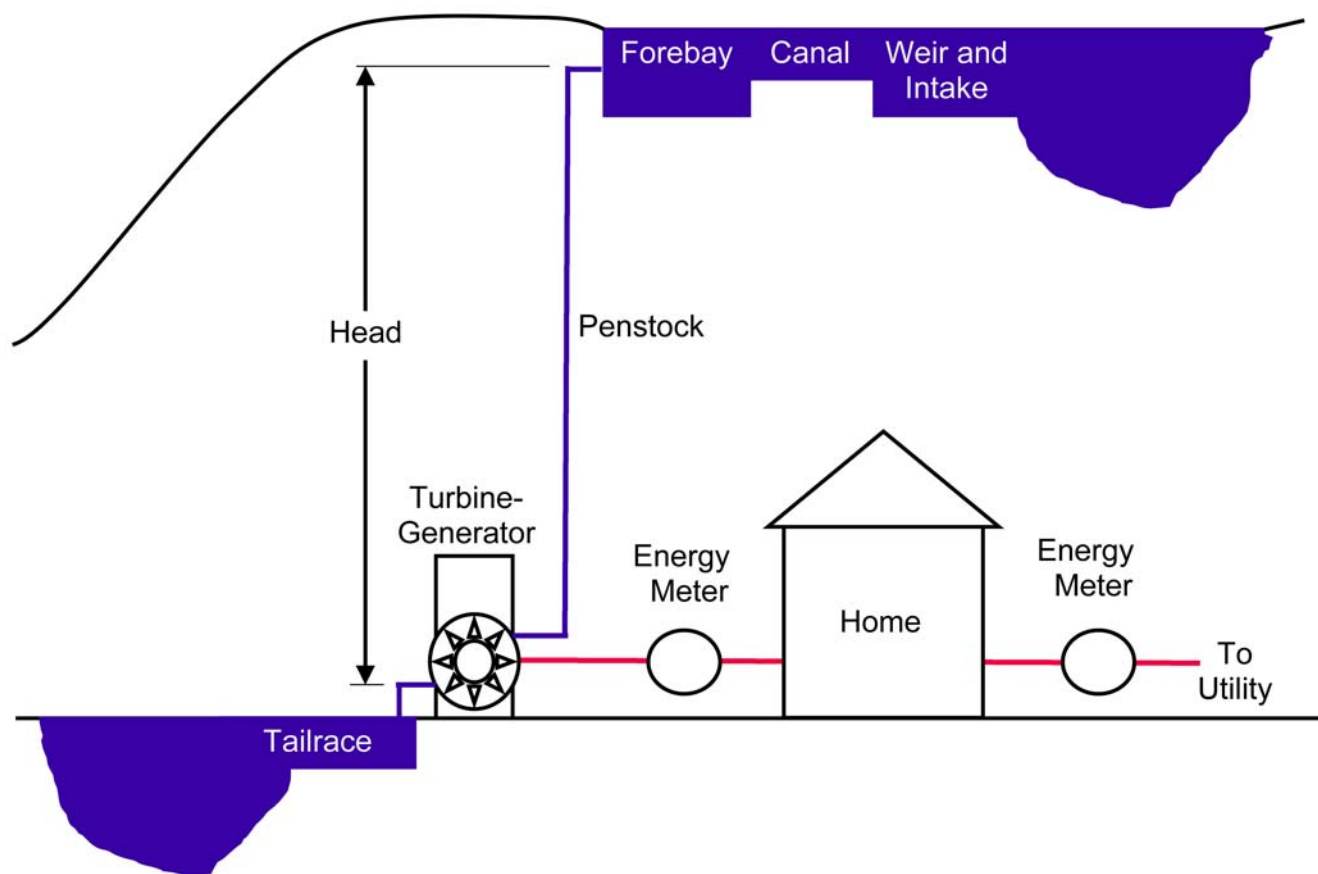


Figure 12-1 - Grid-connected residential microhydropower system. Meter between generator and home is optional.

been the fastest growing energy source in the U.S. over the last decade mainly due to very significant improvements in wind energy technology. The American Wind Energy Association predicts that 6,000 MW of windpower will be installed by the end of 2004. This is enough to power 1.5 million homes. Wind power is produced by the energy of the wind turning aerodynamic blades mounted to a hub. The hub is connected to a shaft that turns a generator. Large utility-scale wind turbines range in size from 50 kilowatts to over four megawatts. Smaller wind towers (under 50 kW) are suitable for residential and agricultural use.

Fuel Cells

A fuel cell is an alternative energy device, but it is not necessarily a renewable energy device. It is only renewable if the source of the fuel used is renewable. A fuel cell is an electrochemical device, like a battery in that

it converts the energy from a chemical reaction directly into electricity and heat. But unlike a battery, which is limited to the stored chemicals within, a fuel cell has the capability of generating energy as long as fuel is supplied. Currently produced fuel cells combine hydrogen and oxygen without combustion to produce electricity. The oxygen comes from the air, while the hydrogen can either be produced from water (using electricity) or extracted from fossil fuels. New fuel cells are being developed that can use fossil fuels directly. Fuel cell technology has been around for over 150 years and it shows great promise in powering vehicles and in providing energy for residential applications.

Residential Renewable and Alternative Energy Systems

There are many opportunities to generate your own electricity and heat using renewable resources. But first you need to realize that you are making an investment,

which can be substantial, and this requires the appropriate research, site considerations, need assessment, and cost effectiveness study. Generating your own electricity and heat may not always make you money or save you money but it can create independence from the utility grid and allow you to generate your own clean and green power. Keep in mind that reducing energy use through conservation and increased efficiency is almost always a cheaper alternative than installing a renewable energy system.

Here are some specific residential renewable energy systems that use the renewable resources that we have discussed above.

Microhydropower Systems

If you have a stream or creek on your property then you might be able to generate electricity using hydropower. Microhydropower systems, if resources and conditions are appropriate, are capable of powering a normal size residence. These systems operate on the same principle as a large hydropower system – moving water turns a turbine, which then drives a generator to produce electricity. Microhydropower does not need to dam the water source to operate but without a dam the power will fluctuate with the normal rise and fall of the creek or stream.

The key components of a successful microhydropower system are the head and flow of the available water resource. The head is the vertical distance that the water falls and flow is the volume of the water. Producing electricity is a combination of proper head and flow and using efficient and properly installed equipment. Utilizing the services of a trained professional to do a complete hydrological study is highly recommended but may be expensive. You can learn to perform your own feasibility study by going to <http://www.eere.energy.gov/consumerinfo/refbriefs/ab2.html>.

Costs will vary on microhydropower systems depending on size of generator, length of pipe needed, whether a dam is needed, and other variables.

Residential Biomass Applications

Biomass is generally used in space heating and cooking as well as an alternative fuel source for vehicles. Wood products are renewable and can be an inexpensive

fuel source for heating and cooking – particularly in areas where wood is plentiful. But the combustion by-products of burning wood still contain potentially harmful pollutants (Chapter 5).

In 1988 the Environmental Protection Agency (EPA) passed emission standards for new wood stoves and after July, 1992 all new wood stoves had to pass these EPA emission standards. This means that new wood stoves burn cleaner and more efficiently than pre-1992 stoves.

Pellet stoves use a variety of biomass ingredients – sawdust, bark, cornhusks, and cardboard – which are compressed together in the form of pellets. Pellet fuel burns much more efficiently than wood, can be fed automatically, and emits fewer pollutants.

EPA rated wood and pellet stoves range from \$800 to \$2,500 dollars.

Biomass sources are also used to produce alternative fuels that burn cleaner than gasoline and emit fewer harmful pollutants into the atmosphere (Chapter 11).

Geothermal Heat Pumps

Using the heat from the earth is a very efficient and renewable method of heating and cooling your home. Geothermal heat pumps (Chapter 5) use the stable temperature of the ground around your home as a source of heat in the winter and cooling in the summer. These systems move heat between the home and ground instead of creating heat by burning fuel and consequently they operate very cleanly and are usually at least three times more efficient than other systems on the market – including those that are energy efficient themselves. A complete geothermal system can also have the ability to provide hot water through a “desuperheater”. A geothermal heat pump system including installation, duct system and hot water delivery can range in cost from \$14,000 to \$20,000 but will save significant money over the long term due to increased efficiency. To identify Geothermal Heat Pump contractors call the Geothermal Heat Pump Consortium at 1-888-333-4472. For more information check out <http://geothermal.geol.vt.edu> and www.geo4va.vt.edu/.

Solar Electric or Photovoltaic (PV) Systems

Photovoltaic (PV) systems differ from solar water heating systems in that they do not use the sun’s energy to

produce heat but instead produce electricity directly from the interaction of sunlight and semiconductor materials. PV products are typically manufactured as individual solar panels that can be added to a structure or mounted on the ground. PV manufacturers, however, are starting to incorporate PV into building materials such as roofing shingles, metal roofing, and window glass. The cost of these products is partially offset by the cost of the building material they replace, and are architecturally very appealing.

There are numerous PV technologies, but most can be grouped into one of two major categories: "crystalline silicon" and "thin film silicon." Crystalline silicon solar cells are cut from crystals of silicon, and their size is limited by the size of crystals that can be produced. Individual cells are electrically connected together to form a PV module. One or more PV modules can be connected together on your roof to produce the desired amount of electricity. Thin film silicon cells differ in that thin layers of semiconductor materials are deposited directly onto a glass or thin metal substrate. The size of the silicon thin films can be much larger than that of silicon crystals, so individual cells can be made much larger and fewer are needed. Crystalline cells have more output for a given cell area, but thin films will cover a larger area for lower cost.

There are three things to consider before purchasing

and installing a PV system: amount of southern exposure, obstructions that might shade or inhibit sun from reaching the modules, and proper space and terrain for installation of the system, including the type of roof that you have.

There are three ways that a PV system can be set up for residential use:

- Grid-connected PV systems interface directly with your electric utility connection and allow for excess solar generation to be put back on the grid. When the PV system is not meeting the consumption demand then the consumer will receive electricity from the grid. In Virginia net metering allows customers to receive credit for excess electricity generated from their PV systems, but the total amount of PV power connected to the grid is limited by law.
- Grid-connected systems with battery storage work like ordinary grid-connected systems, but the battery storage allows you back up capability in case of a power outage.
- Independent or off-the-grid systems operate independently. They are stand-alone systems appropriate in situations where there is no electric service to begin with. Independent systems require battery storage to

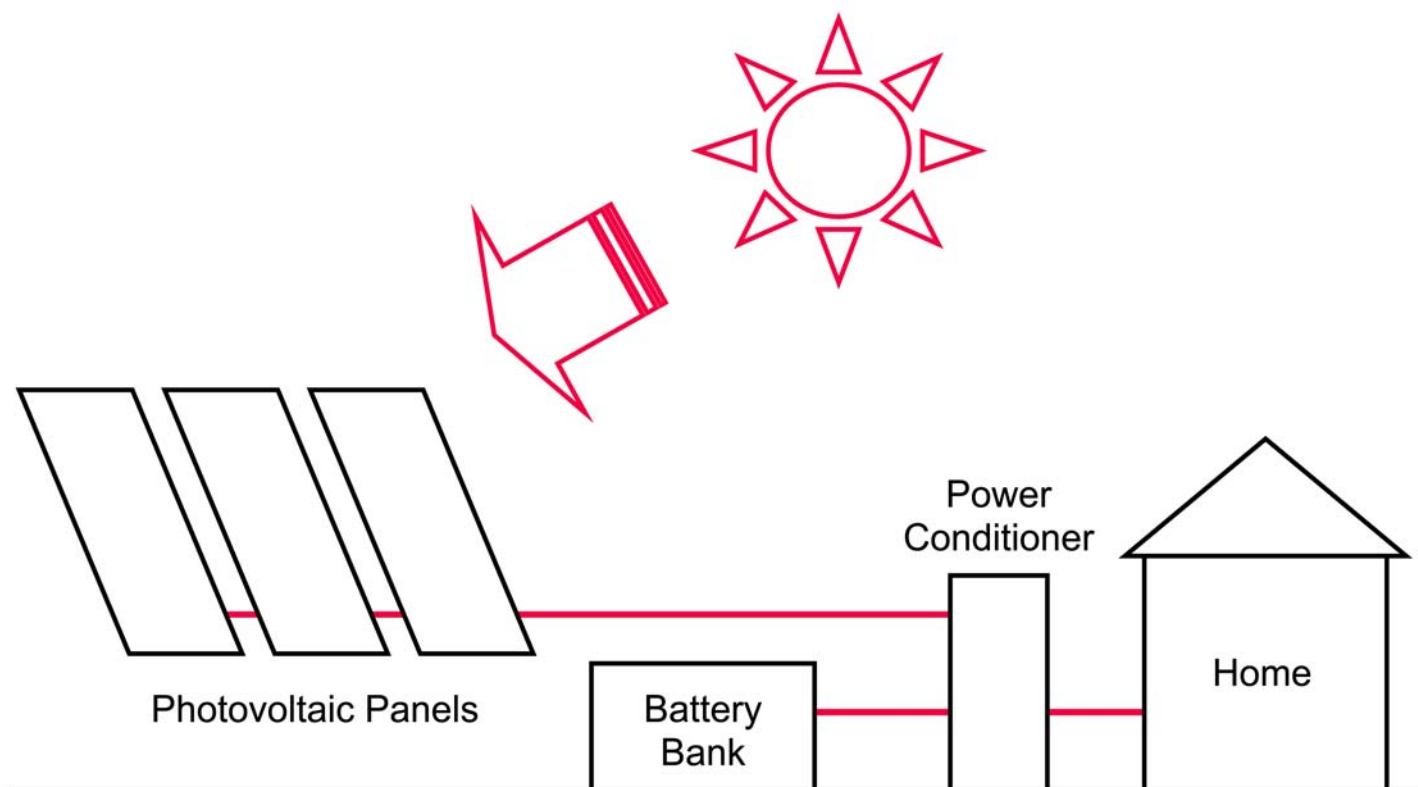


Figure 12-2 - Off-grid residential photovoltaic system.

provide power at night and in cloudy weather.

Determining the size of your system is an important consideration because this will determine your capacity as well as your initial cost. Working with a professional PV installer is a good first step in determining your electrical output needs and cost options.

There are loan programs available that might help to offset the initial costs for a PV system; they will be discussed later. PV systems are expensive, but a PV system is quiet, is non-polluting, and requires no fuel. Since solar energy is a growing technology, the price of equipment and installation will decrease over time. The price of fossil fuels and electricity, by contrast, will probably continue to increase.

Solar technology that is installed at the time of home construction can be more cost effective if integrated in such a way as to offset the cost of traditional building materials. Solar costs can be rolled into an energy efficient mortgage package.

To identify solar equipment manufacturers and solar installers contact the American Solar Energy Society at www.ases.org and the Maryland – DC – Virginia Solar Energy Industries Association at www.mdv-seia.org.

Wind Energy Systems

A small residential wind energy system can provide significant electrical power if certain conditions exist:

- Do you have enough wind where you live? Is the annual average mile-per-hour wind speed sufficient?
- Do zoning or land use requirements disallow tall towers in your neighborhood?
- Is there enough space for installation and operation?
- Is it economically feasible?

Wind energy is clean, non-polluting, and capable of providing enough electricity to power your home.

The size of your system depends on how you plan to use the power that is generated. Small wind turbines can range in size from 20 watts to 100 kilowatts (kW) with a 20-500 watt system being used to charge batteries and a 5 to 15 kW system being used to power a home using 700 to 800 kWh per month.

Residential wind systems consist of a rotor or blades,

a generator mounted on a frame, a tower, the necessary wiring and the “balance of system” components: controllers, inverters, and possibly batteries. Through the spinning blades, the rotor traps the kinetic energy of the wind and converts it into rotary motion to drive the generator, which produces electricity. The diameter of the rotor and the maximum wind speed determine the amount of power that can be produced. Higher towers give more power both by allowing larger rotors and by reaching heights where wind speeds are greater. A 60 to 120 foot tower (5 to 10 stories) is common for small wind energy systems. Wind energy systems can be stand-alone or connected to the electric utility grid allowing the consumer to take advantage of net metering in the same manner as solar systems (discussed above).

A rule of thumb for estimating cost is \$3,000 to \$6,000 per kilowatt. A typical 10kW system costs about \$47,000 installed and produces 900 kWh at an annual average wind speed of 12 mph, which is fairly common in Virginia when using a 120 foot tower. As is the case with most renewable energy systems and energy efficient products, the initial cost is high but the savings realized over the long term may be significant.

For further information and to locate and identify equipment manufacturers and installers check out the American Wind Energy Association www.awea.org, the U.S. Department of Energy Wind Energy Program www.eren.doe.gov/wind/, and the Virginia Wind Energy Collaborative <http://web.jmu.edu/vwec>.

Residential Fuel Cells

Residential fuel cells represent a clean, efficient, non-polluting source of electrical power. Fuel cells are a renewable energy technology only if their fuel comes from renewable sources, but even if they use fossil-based fuels they use them cleanly and very efficiently.

In a typical fuel cell (see Figure 12-4, page 156) hydrogen molecules are broken down into negatively-charged electrons and positively-charged hydrogen ions at the anode. The electrons flow through the load (delivering power), while the hydrogen ions flow through the electrolyte. At the anode the hydrogen ions and electrons combine with oxygen molecules to form water. Since a single fuel cell has an output of only about one volt, many

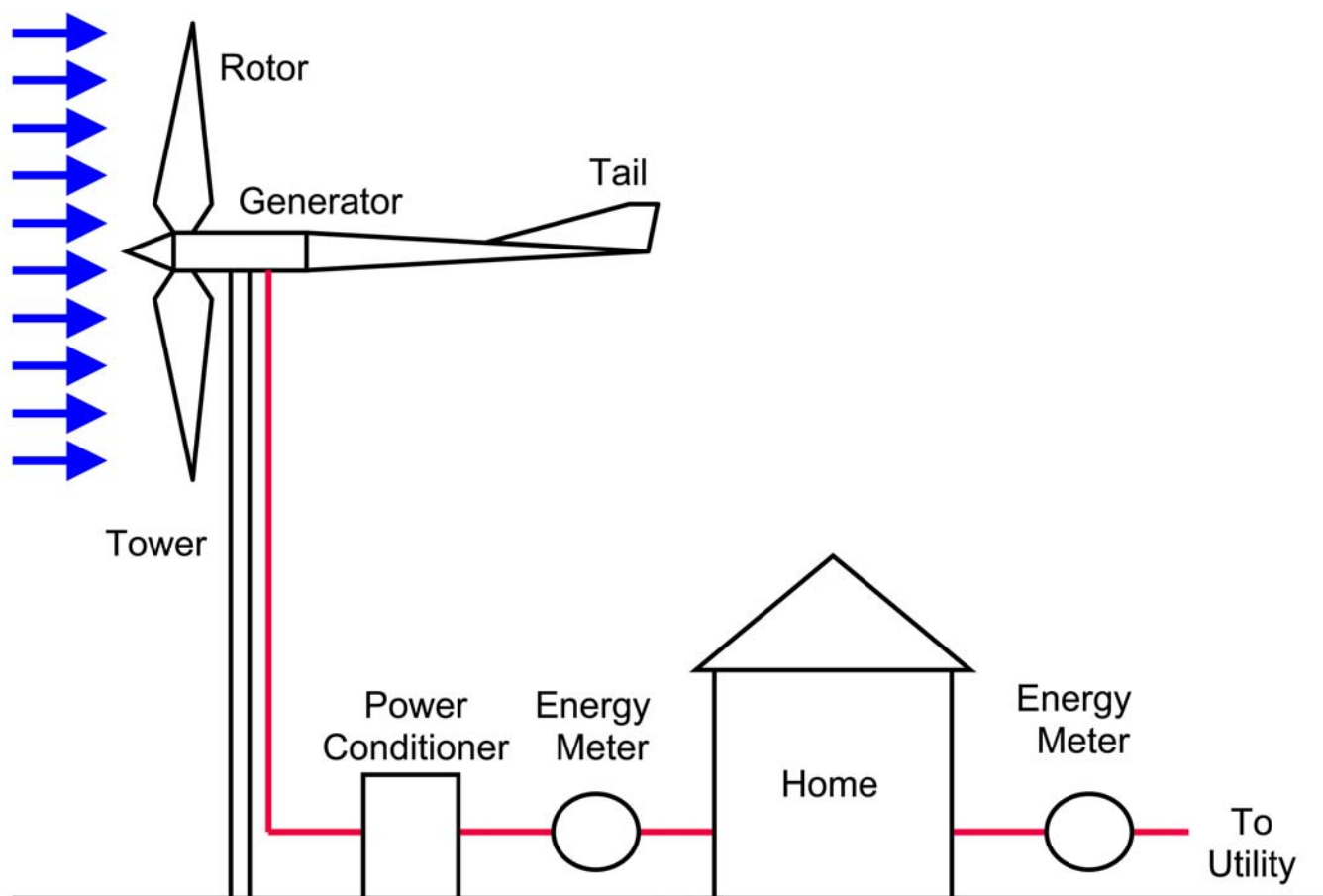


Figure 12-3 - Grid-connected residential wind energy system. Meter between power conditioner and home is optional.

are combined to form a residential power package.

The benefits of residential fuel cells are numerous:

- Fuel cells are very efficient because they convert chemical energy directly into electrical energy without combustion.
- They can operate independent of the utility grid or in conjunction with the grid.
- Unlike other renewable systems, fuel cells can provide power on demand. Independent systems thus do not require battery storage.
- Fuel cell emissions are clean: if they are using hydrogen fuel their combustion product is simply water vapor. Fuel cells that require a reformer to convert fuels to hydrogen emit both water vapor and carbon dioxide.
- Fuel cells are completely compatible with other renewable systems like PV and wind and make very

successful hybrid systems.

- Fuel cells are fuel flexible and can use just about any fossil fuel: propane, natural gas, methanol, ethanol, oil, or gasoline. They can also use renewably-generated hydrogen.
- Fuel cells run continuously and are easily maintained although maintenance can vary depending on the technology of the fuel cell.

Some disadvantages to fuel cells are:

- Residential fuel cell technology is very new and still being tested
- The cost of a residential fuel cell is still high - \$6,000 to \$10,000 for a 5kW system that could power a standard size home.

A residential fuel cell system consists of a fuel processor that converts fuel into hydrogen, a fuel cell stack that converts the hydrogen into direct current electricity,

batteries for storing power, and an inverter to produce alternating current. For further information on fuel cells check out www.fuelcells.org .

Virginia Programs that promote Renewable Energy

Virginia offers a low-interest loan program, net metering, property tax exemptions in some localities, and service programs that promote and encourage the use of renewable energy.

Renewable Energy and Energy Efficiency Loan Program

The Virginia Housing and Redevelopment Authority (VHDA) administers a low-interest loan program for low and moderate income homeowners. This program, created in 1978, provides loans for home repairs that reduce energy consumption or reduce dependence on conventional

energy sources. All renewable energy technologies are eligible and this includes passive solar space heat, active solar water heat, active solar space heat, solar thermal electricity, photovoltaic systems, wind energy systems, biomass, hydropower, geothermal, and waste. The interest rate is 6.75% and loan amounts range from \$1,000 to \$25,000 for terms from 6 months to 20 years. Contact VHDA for more information at 804-343-5751 or www.vhda.com .

Local Option Property Tax Exemption

This Virginia statute, section 58.1-3661 from the Code of Virginia allows any county, city, or town to exempt solar-energy equipment or recycling equipment from local property taxes. Residential, commercial, or industrial property is eligible. The statute defines solar-energy equipment as any “application that would otherwise require a conventional source of energy”. This includes

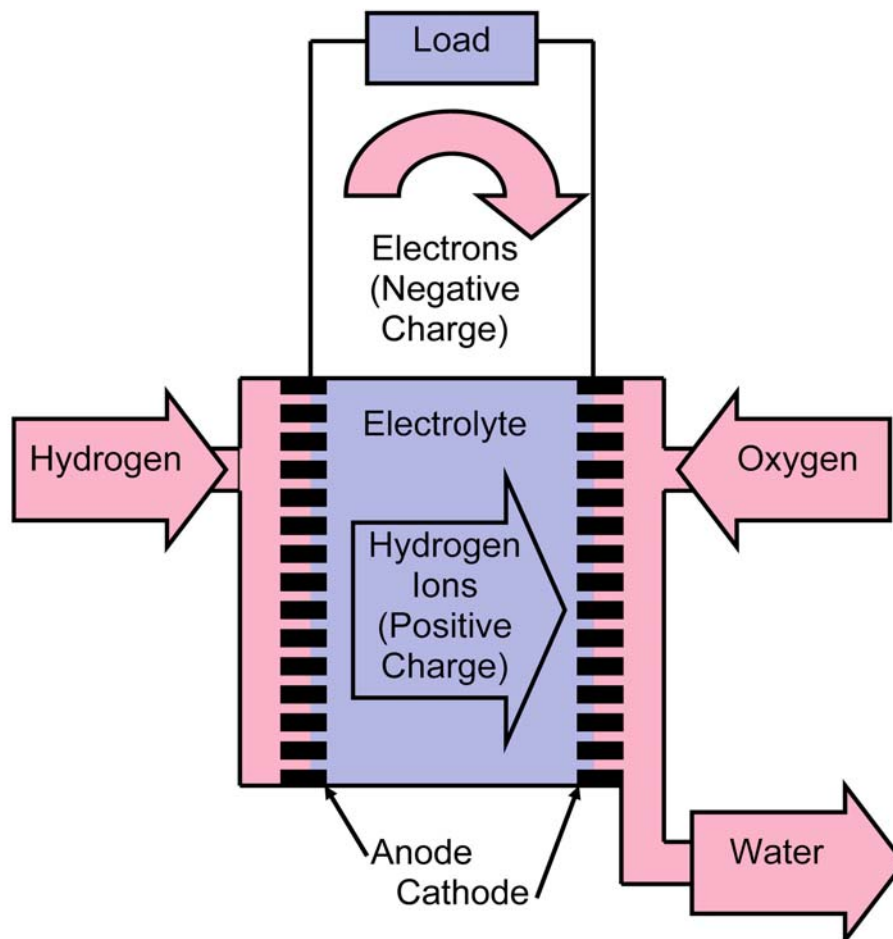


Figure 12-4 - Schematic of basic hydrogen-oxygen fuel cell operation.

solar space heat, solar water heat, solar thermal electricity, and photovoltaic systems. Contact your local Commissioner of Revenue to see if your county offers the exemption and for further information.

Net Metering

“Net metering” allows customers to receive the full retail value of any excess electricity they generate from their solar, wind, or hydroelectric system. When you use power from the grid you pay for it, but when you supply excess renewably-generated power to the grid your electric meter essentially spins backward and subtracts kilowatt hours from your bill. The law requires all utilities under the jurisdiction of the State Corporation Commission to offer net metering to residential systems of 10 kW or less and to non-residential systems of 25 kW or less. The law limits the amount of net metered generation in any particular utility distribution territory to 0.1% of the previous year’s peak electricity demand. Rate payers can apply the credit for electricity generated from their system to the following month; however, at the end of the year, any excess generation is granted to the utility. Contact your local utility provider or the Virginia Department of Mines, Minerals and Energy for more information.

Program to Promote the use of Wind in Virginia

Several groups in Virginia have come together to form the Virginia Wind Energy Collaborative (VWEC) to address issues related to wind power development in the state. Information about VWEC’s activities is available on their website at www.jmu.edu/vwec.

One of the key participants, James Madison University manages the Virginia State-Based Anemometer loan program (SBALP), which loans landowners a 20 meter tall wind measuring device that measures the wind speed and direction. This wind data can then be used to determine whether a wind turbine is appropriate for their location. For more information call 540-568-2560, contact the Integrated Science and Technology Department at JMU, or visit <http://www.jmu.edu/sbalp/>.

Energy Tips and Recommendations

1. Consider the use of renewable energy systems that produce clean and non-polluting energy. The initial cost or investment may be high but over the long term the savings can be significant. You will also be

making an important commitment to saving our natural resources and preserving the environment.

2. If you have a stream on your property, you may be able to develop a small microhydropower system that can produce enough electricity to power your home.
3. Space heating is a low-cost way in which to incorporate biomass into a residential renewable application.
4. Geothermal heat pumps, which use the heat of the earth, to provide heating and cooling for the home are three times more efficient than conventional energy efficient furnaces.
5. Solar electric systems (PV systems) use the power of the sun to produce electricity. Solar panels mounted on your roof or near your home can provide clean, non-polluting, and renewable energy to power your home.
6. Small residential wind energy systems provide a clean, non-polluting source of electricity. You must have a sufficient average annual wind speed and enough installation space for wind energy to be effective.
7. Consider using hybrid power systems, which combine different renewable energy sources to produce electricity.
8. Fuel cells combine hydrogen and oxygen without combustion to produce electricity. They are efficient, and when fueled with pure hydrogen their only emission product is water vapor. They represent an exciting new technology that is still a few years away but may represent the residential power source of the future.
9. Take advantage of existing programs to help offset the cost of renewable energy systems and to receive services and expertise.
10. Keep in mind that reducing energy use through conservation and increased efficiency is almost always a cheaper alternative than installing a renewable energy system.